Species sensitivity distributions and exposure concentrations; placing recent results into context

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Background

- Recent focus on ammonia in Delta
  - March 2009 white paper
  - March 2009 research framework
- Outstanding questions
  - "Are the US EPA chronic and acute criteria adequately protective for Delta and Suisun Bay species?"

Approach

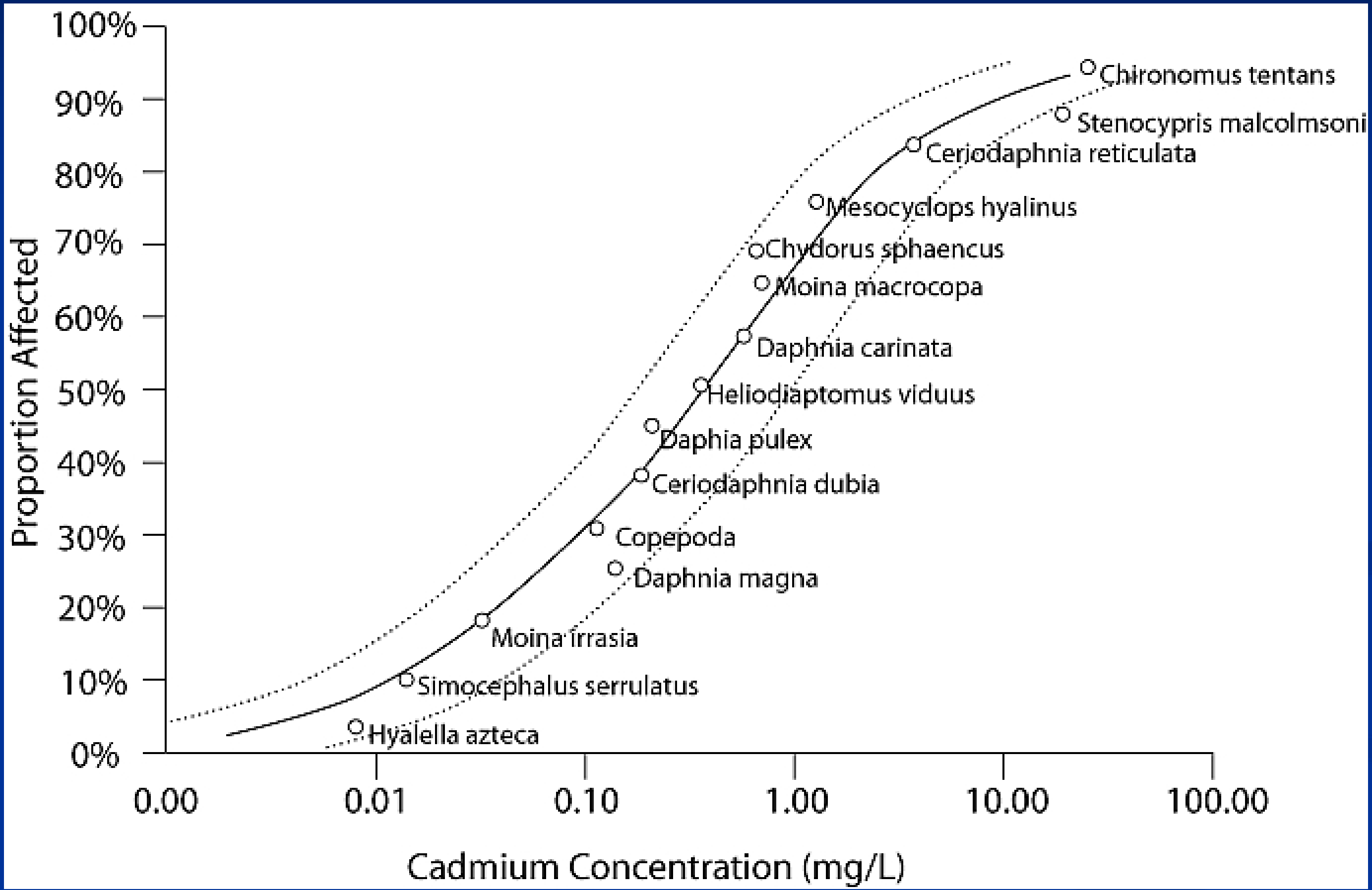
- Build species sensitivity distributions for unionized ammonia
- Determine environmental concentrations at various locations in Delta
- Estimate risk
- Compare to current standards

Species Sensitivity Distributions

- A statistical distribution describing the variation among a set of species in their response to a chemical
  - Represented as a cumulative frequency distribution function
  - Can be used in “forward” or “inverse” manner

Forward and Inverse Use

- Inverse
  - Calculate a “safe” concentration, HC_5
  - Establishes the environmental criterion necessary to protect 95% of species
- Forward – ecological risk assessment
  - Estimation of the ambient concentration at a location
  - Use SSD to determine the Potentially Affected Fraction



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Proportion Affected
0.00
0.01
0.10
1.00
10.00
100.00
Cadmium Concentration (mg/L)
Chironomus tentans
Stenocypris malcolmsoni
Ceriodaphnia reticulata
Mesocyclops hyalinus
Chydorus sphaencus
Moina macrocopa
Daphnia carinata
Heliodiaptomus viduus
Daphia pulex
Ceriodaphnia dubia
Copepoda
Daphnia magna
Moina irrasia
Simocephalus serrulatus
Hyalella azteca

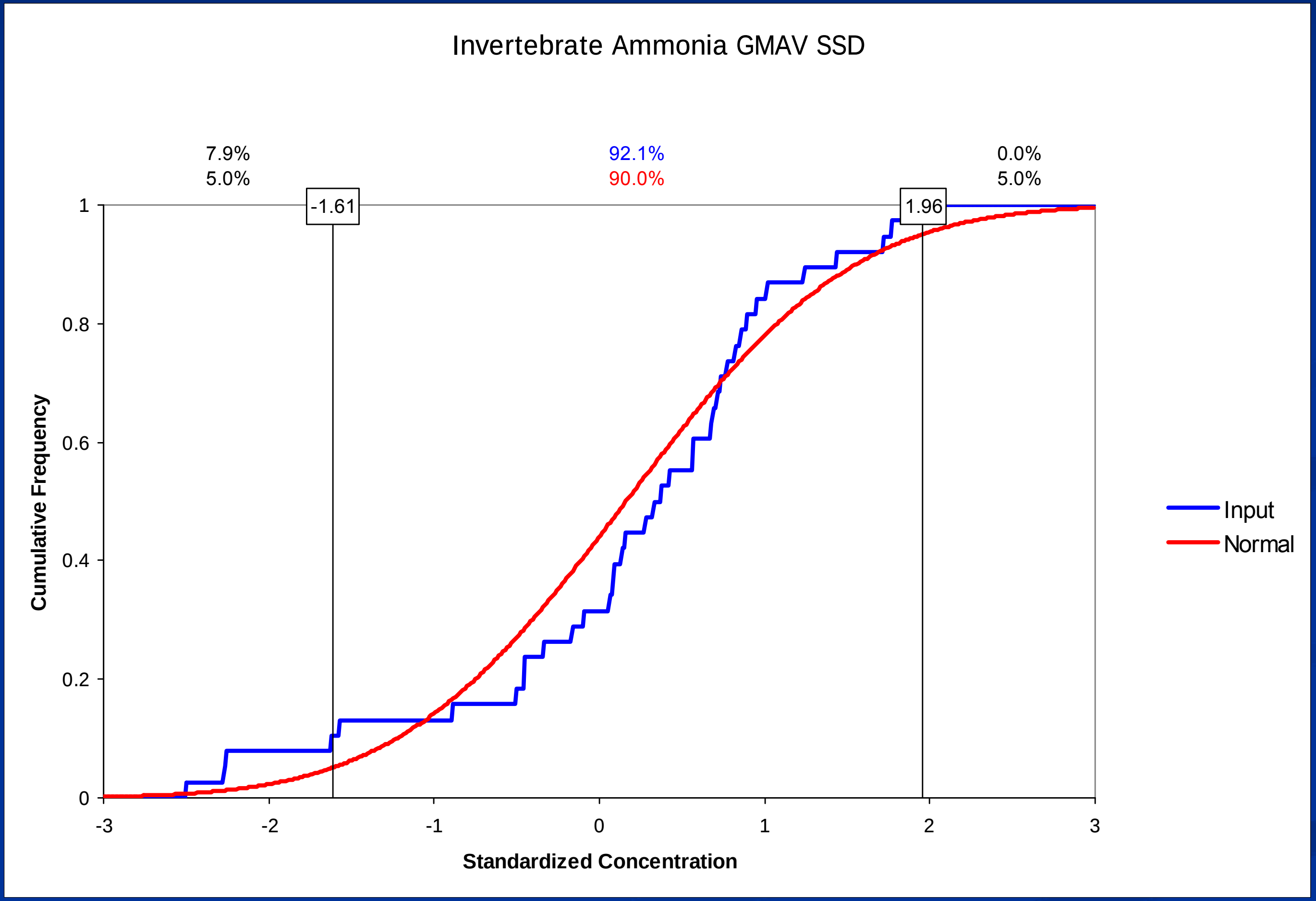
Construction of SSD for Unionized Ammonia

- Raw data
  - Studies from US EPA (1999) criteria document and additional recent toxicity studies
- Calculate Genus Mean Acute Values
  - Corrects for over-representation of some species such as *Oncorhynchus mykiss*
- Apply geometric mean of the acute-to-chronic ratio to obtain chronic HC_5
- Calculate sensitivities of HC_5 to each GMAV

Data Manipulation

- Calculate GMAV for fish and invertebrates separately
- Transform GMAV to Log_{10} scale
- Standardize to distribution $\mu = 0, \sigma = 1$
- Plot SSDs

Invertebrate SSD



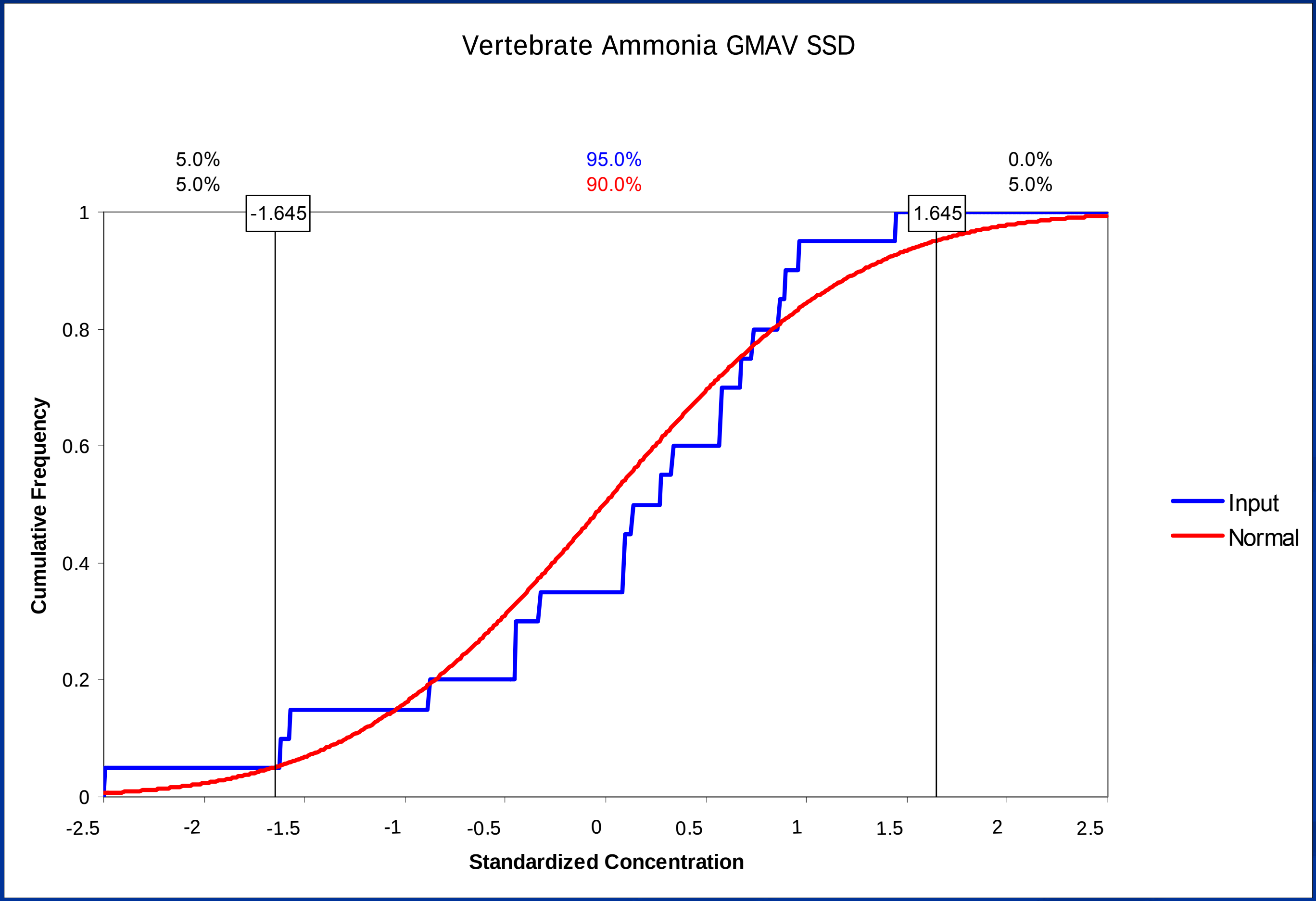
SSD Statistics

- Acute invertebrate HC_5 = 0.259 mg/L unionized ammonia (n = 18)
  - 95% confidence bounds set by Bayesian analysis (Aldenberg et al. 2002)
  - LB AHC_5 = 0.092 mg/L; UB AHC_5 = 0.458 mg/L
- GMACR = 3.17
- Chronic invertebrate HC_5 = 0.082 mg/L unionized ammonia (Eq 17.23 in Warren-Hicks et al. 2002)
  - LB CHC_5 = 0.029 mg/L; UB CHC_5 = 0.145 mg/L

Sensitivities of HC_5 to GMAC Values

Genus	GM NH_3 LC_{50}	Sensitivity Upper	Sensitivity Median	Sensitivity Lower
Eurytemora	0.12	0.379	0.276	0.208
Pseudodiaptomus	0.12	0.377	0.275	0.207
Callibaetis	2.95	0.004	0.021	0.032
Philarctus	10.2	-0.140	-0.078	-0.036

Vertebrate SSD



SSD Statistics

- Acute vertebrate HC_5 = 0.273 mg/L unionized ammonia (N = 20)
  - LB AHC_5 = 0.157 mg/L; UB AHC_5 = 0.385 mg/L (Aldenberg et al. 2002)
- GMACR = 5.59
- Chronic vertebrate HC_5 = 0.049 mg/L unionized ammonia (Eq 17.23 in Warren-Hicks et al. 2002)
  - LB CHC_5 = 0.028 mg/L; UB CHC_5 = 0.069 mg/L

Sensitivities of HC_5 to GMAC Values

Genus	GM NH_3 LC_{50}	Sensitivity Upper	Sensitivity Median	Sensitivity Lower
Hypomesus	0.15	0.364	0.270	0.204
Morone	0.28	0.253	0.192	0.150
Micropterus	1.17	0.007	0.020	0.029
Gambusia	2.63	-0.133	-0.077	-0.040

Comparisons

- VA HC_5 = 0.273 mg/L
- VC HC_5 = 0.049 mg/L
- IA HC_5 = 0.259 mg/L
- IC HC_5 = 0.037 mg/L

- Delta smelt LC_{50} = 0.147 mg/L
- Delta smelt NOEC = 0.066 mg/L
- Eurytemora LC_{10} = 0.078 mg/L; ACR HC_5 = 0.025 mg/L
- Pseudodiaptomus LC_{10} = 0.072 mg/L; ACR HC_5 = 0.023 mg/L

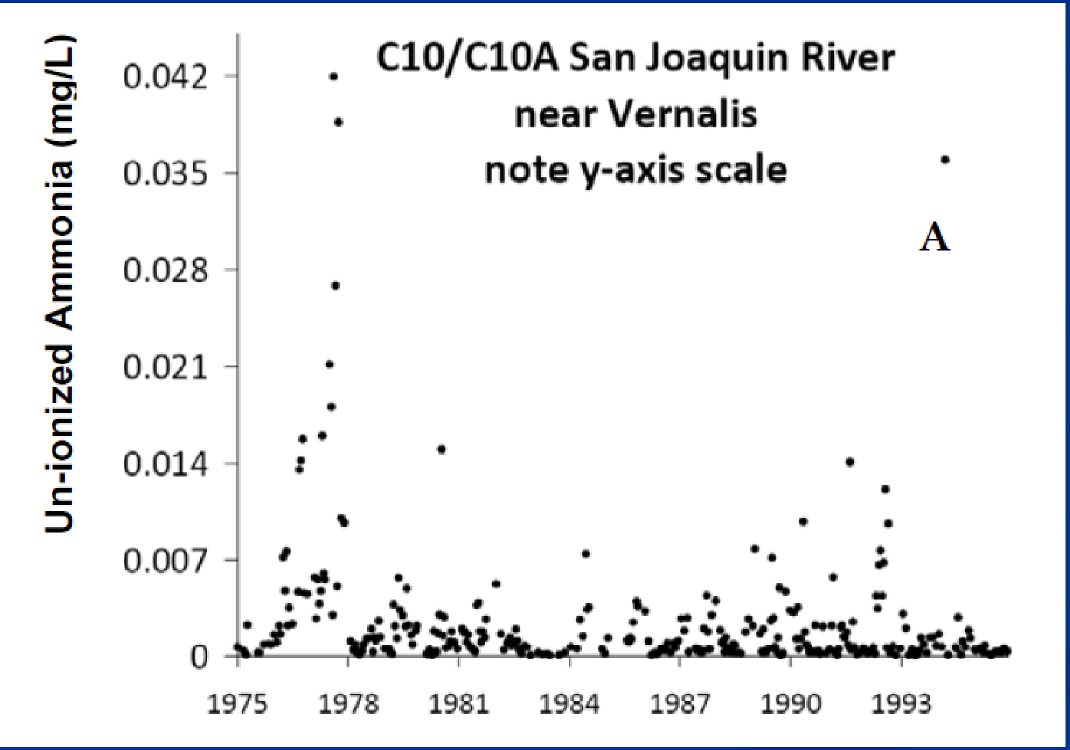
Exposure and Risk

- Risk defined as the probability of some randomly selected Exposure Concentration (EC) exceeding a randomly selected Species Sensitivity (SS)
  - Assumes the SSD represents the sensitivities of species in system
  - Assumes the time scale of measurements of EC “matches” the time scale of measurements used in toxicity studies

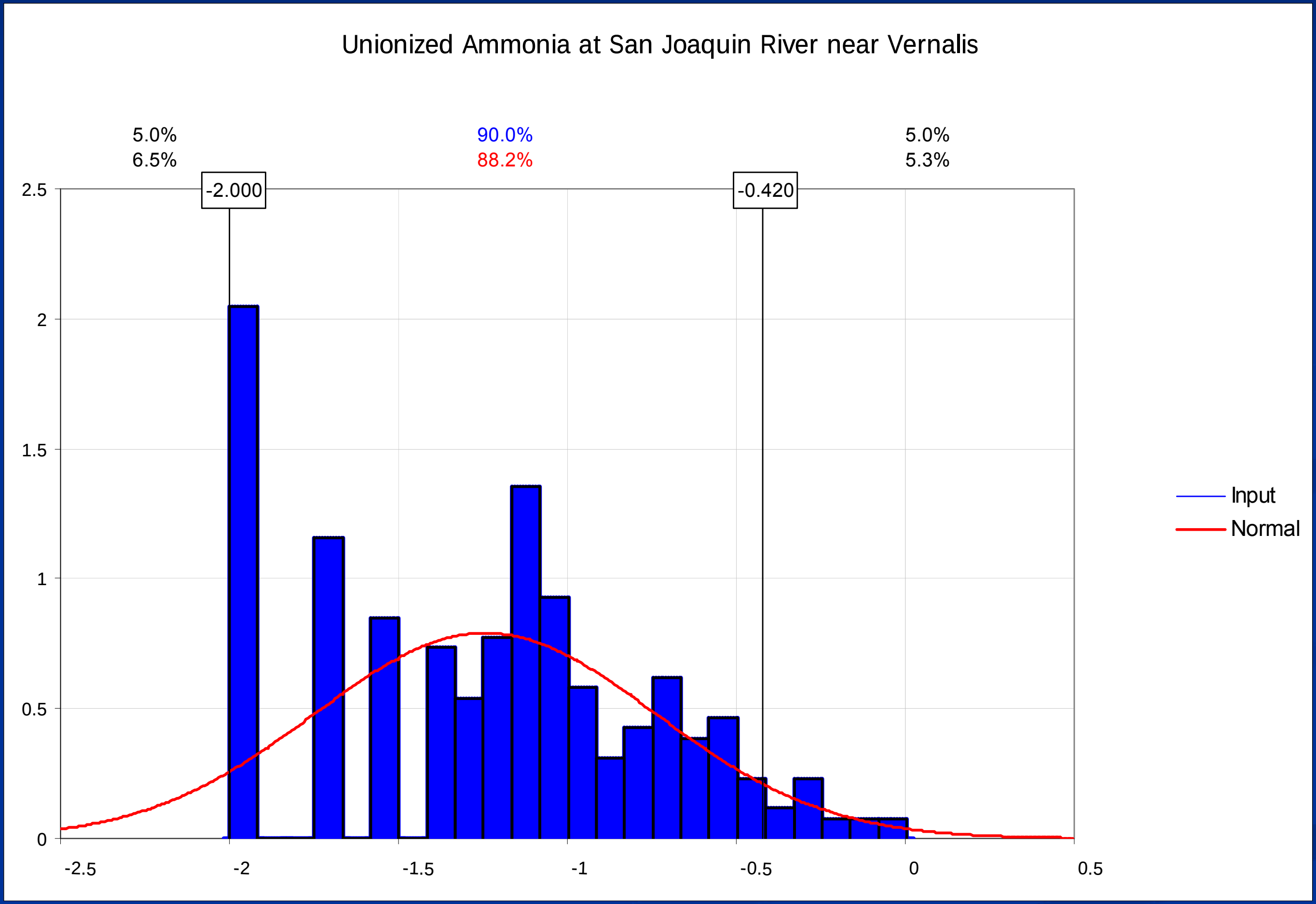
Calculations

- Simplified if both SSD and EC are normally distributed
- Standardize distribution of Log_{10}EC values to distribution of Log_{10}SS values
- Look up probabilities of risk in Table 5.3 of Aldenberg et al. 2002
- Calculated risk from DWR data for period 1975-1995 (uncorrected for salinity)
  - San Joaquin River near Vernalis (C10)
  - Sacramento River above Pt. Sacramento (D4)

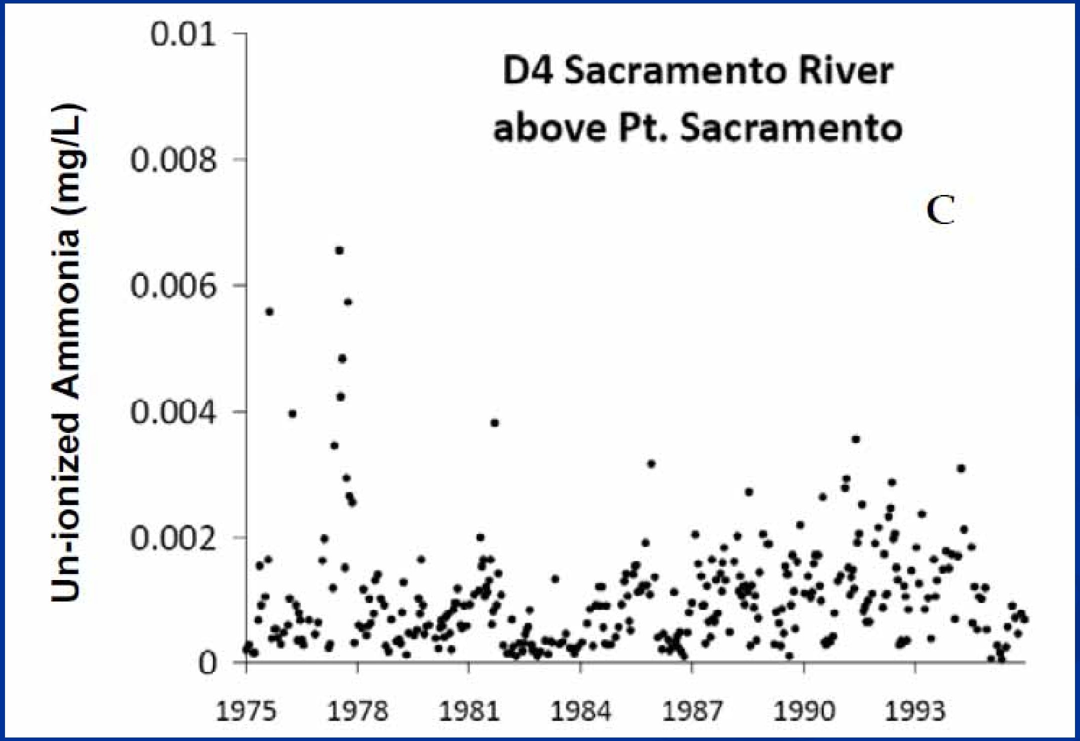
San Joaquin River near Vernalis – Raw Data



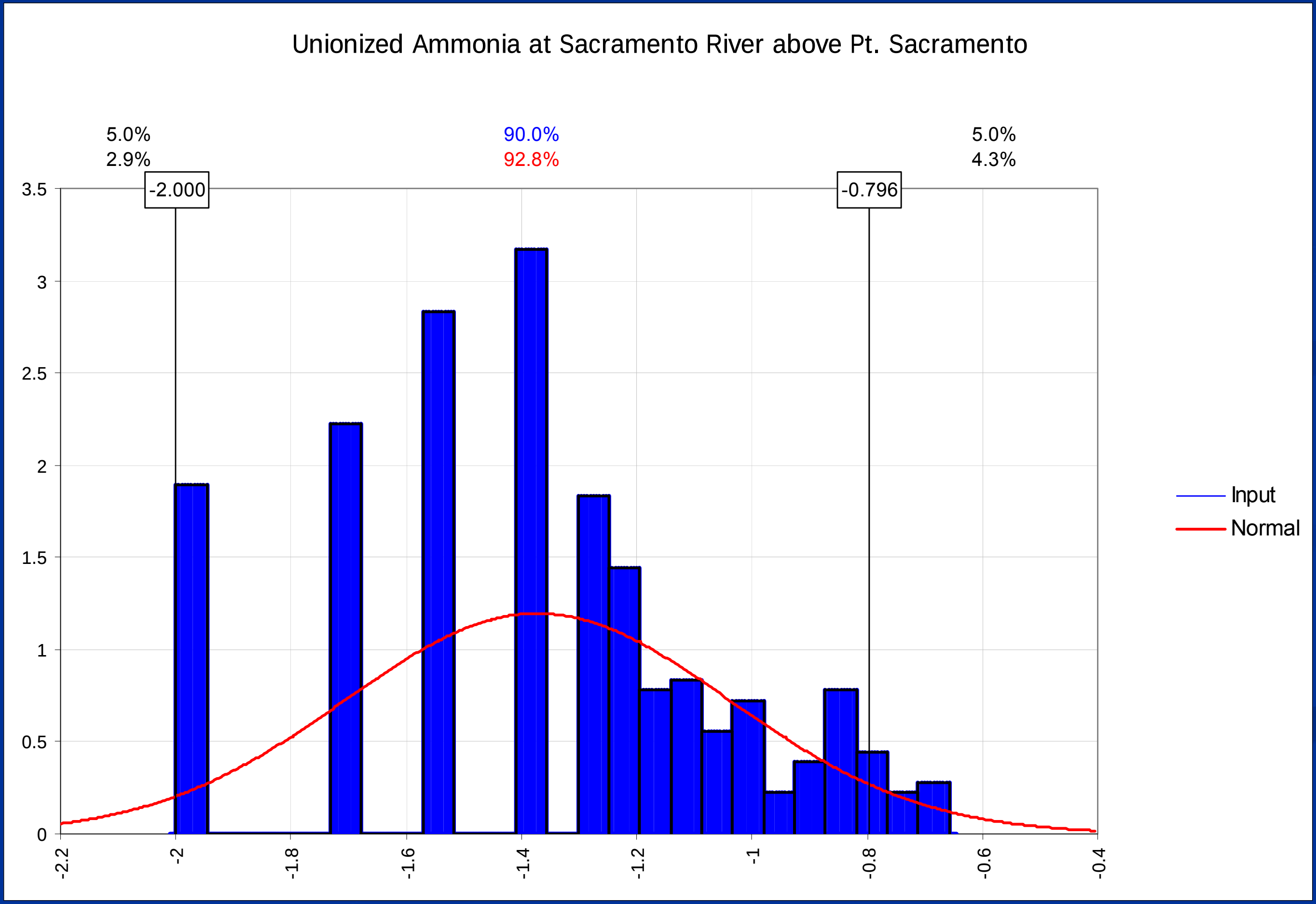
San Joaquin River near Vernalis – Frequency Distribution



Sacramento River above Pt. Sacramento – Raw Data



Sacramento River above Pt. Sacramento – Frequency Distribution



Risk Calculations - Vertebrates

- San Joaquin River near Vernalis (C10)
  - Risk = 1.29 – 3.86%
- Sacramento River near Pt. Sacramento (D4)
  - Risk = 0.13 – 0.7%

Conclusions

- Are current species' toxicity data reflective of Delta fauna?
  - Chronic HC_5 values would not be protective of 3 Delta species
- US EPA criteria may be an order of magnitude too high
- Ammonium measurements not collected at correct scale to allow comparisons to toxicity data